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XXXV.—*The Classification of the Animal Kingdom, with reference to the newer Zoological Systems.* By Dr. T. Margó *.

The sum of our knowledge of the anatomical and histological structure as well as the development of different animals has advanced of late years with wonderful rapidity. In accordance with this the views of zoologists as to the classification of the animal kingdom have also changed continually. It is therefore no wonder that with such frequent alterations of the system younger naturalists, who may be inclined to regard the system as the foundation of the science, find themselves at first in no small difficulty, until, subsequently, after they have penetrated more deeply into the interior of nature, and recognized the essence of zoology more accurately, they arrive at the right view, that in reality classification or taxonomy is by no means the foundation of the science, but rather only the roofing-in of the structure raised upon the foundation of morphology and embryology.

As the main cause of the vacillations nowadays apparently occurring in classification we must undoubtedly regard only the enormous advance lately observable in the domain of morphology and embryology, an advance which from year to year becomes more and more evident by the discovery and exact observation and demonstration of new facts of great importance to science, which naturally lead to changes, modifications, and rectifications of opinion. From this it is easily understood why we meet with different systems in the different treatises and manuals of zoology, and how, even with the same naturalist, the system may change essentially from time to time.

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* Translated by W. S. Dallas, F.L.S., from the 'Mathematische und naturwissenschaftliche Berichte aus Ungarn,' Band i. pp. 234–260 (1883).

Thus, for example, Huxley's system of the year 1875 is essentially different from that followed by him at a later period (1878); for while this naturalist formerly adopted the formation of the embryonal nutritive cavities, the mouth, and cœloma as the foundation for a phylogenetic grouping of animals, and accordingly divided the Metazoa into Archæostomata and Deuterostomata, and the latter again, in accordance with the mode of formation of the cœloma, into Enterocœla, Schizocœla, and Epicœla, and consequently the whole animal kingdom into twenty-six stems or phyla *, the same author, some years later, leaving the phylogenetic point of view and the descent of animals entirely out of consideration, divided the whole animal kingdom, exclusively from morphological types, into eight large typical groups. We find similar alterations also more or less in the classifications of Gegenbaur, Ray Lankester, Claus, &c.

Further vacillations of many kinds may also be produced in the system by the circumstance that the individual views of the different naturalists as to the value and usefulness of the facts ascertained by observation sometimes do not exactly agree, by which means the combinations and deductions from those facts may often lead to quite different final results. But if we consider not so much these combinations, but rather the already ascertained facts which constitute the proper subject, the true foundation of classification, we come without much difficulty to see that the systems, however different they may be, nevertheless contain many generally admissible truths, which are raised beyond the least doubt.

We may consider animals like all other natural objects—treat them systematically or group them from different points of view, and combine them at pleasure into a system. Every zoological system, if it be objective and founded upon already demonstrated facts, has its justification, and when considered from a certain standpoint may have its value and use. Thus,

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* Huxley, "On the Classification of the Animal Kingdom," in Quart. Journ. Micr. Sci., January 1875.

as is well known, there are *Natural-history systems*, such, for example, as the systems of the old school, which were chiefly founded upon the external form and vital relations of the animals. There are systems chiefly founded upon *anatomical facts*, such as the system proposed at the beginning of the present century by Cuvier, who divided the whole animal world into four principal types (Vertebrata, Mollusca, Articulata, Radiata); and there are also systems established upon *embryological facts*, such as that of C. Semper, who, as is well known, has quite recently attempted to determine accurately the relationships of animals according to the embryonal primitive kidneys or segmental organs, and to classify the Metazoa phylogenetically upon this exclusively embryological basis *.

The discovery of segmental organs (primitive kidneys) in the embryos of sharks, for which we are indebted to Professor C. Semper, and in part also to the English embryologist F. Balfour, is doubtless so far of great importance to the transformation-theory, that it furnishes a fresh proof of the fact that the Vertebrata and Evertebrata, namely the Vermes, possess in common organs which are homologous from a morphological point of view.

It is, however, questionable whether it is permissible to ascribe to the above-mentioned organs so great an importance, and to found upon them exclusively a classification of the entire animal kingdom. I would ask, is the relationship between the other Vertebrata and the Annelida really greater than between the other Vertebrata and *Amphioxus*, or between this latter and the Ascidia?

Many zoologists believe that they can give science a new direction by selecting according to their judgment one of the embryonal organs, or any phenomenon of the embryonal organism, in order to found upon it a phylogenetic classification, in the hope of being able in this way to establish a natural relationship of the groups of animals. We may readily admit that embryonal characters are of greater value in taxonomy than characters of the fully developed animals derived from anatomy or biology, as in the latter the characters may much more easily suffer change by adaptation and change of function; but we think we may assert with certainty that embryonal characters taken by themselves (even if they relate to the most important organ of the embryo) are far from being sufficient for the sure establishment of the descent of one of the smaller groups of animals, and still more of the whole animal kingdom.

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* C. Semper, 'Die Verwandtschafts-Beziehungen der gegliederten Thiere' (Hamburg, 1876), 2 vols.

We think that we must speak in the same way of the system made known by M. A. Giard *. This zealous and otherwise distinguished zoologist, as is well known, took as the basis of his new classification of the animal kingdom the *amnion*, that is the embryonal envelope originating from the ectoderm, and so, according as the embryos possess or are destitute of such an envelope, divided the Metazoa into two great groups (Hymenotoca and Gymnotoca). But that the presence or absence of an embryonal envelope can by no means serve as a proof for or against genealogical relationship, and therefore cannot suffice for the establishment of a grouping of the animal kingdom resting upon natural affinity, will be at once seen by any one who will compare with each other all the different groups of animals, such as the Vertebrata, Tunicata, Arthropoda, Echinodermata, Acanthocephala, Trematoda, Cestoda, Turbellaria, and Nemertina, which Giard united in the group of the Hymenotoca on account of the embryonal envelope observed upon their embryos, although in every other respect many of them stand very far apart. Observation shows us, moreover, that even groups of animals, *e. g.* fishes, amphibia, reptiles, birds, and mammals, which demonstrably belong to one and the same natural stem, differ from each other in this respect, that while some of them (mammals, birds, and reptiles) during their embryonal existence are in possession of an amnion, others, on the contrary (Amphibia and fishes), are quite destitute of any thing of the kind. From this, however, we may evidently conclude that the amnion, or the embryonal envelope, where it is actually present, is to be regarded as originally not an inherited character, but one acquired by adaptation. As such it might originate, under the action of exactly similar conditions in quite divergent animals, even belonging to different stems, and quite independently of each other. It would therefore be very precipitate to conclude at once as to the true relationships of animals, in all cases, from the presence or non-presence of such a character.

We must therefore regard all the different endeavours of systematists to group animals exclusively in accordance with one character, whether morphological, embryological, or biological, external or internal, as mere experiments,—such a grouping or classification of animals can never be the true expression of their natural affinities.

It was an error on the part of L. Agassiz to attempt to group the fishes according to the form and structure of their scales into cycloid, ctenoid, ganoid, and placoid fishes, or when the same naturalist referred the *Vorticellæ* to the group Bryozoa merely from their external similarity, without at all taking into account the important differences in their structure and development; and the classifications of the Medusæ attempted by Gegenbaur according to the presence or absence of a velum (*Craspedota* and *Acraspeda*), by Forbes * with exclusive reference to the marginal corpuscles (*Steganophthalmata* and *Gymnophthalmata*), and by Eschscholtz † according to the position of the generative organs (*Phanerocarpæ* and *Cryptocarpæ*) are equally unsatisfactory.

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* 'Revue scientifique de la France et de l'étranger' (1876), no. 38.

There is consequently no doubt that for the foundation of a truly natural or so-called phylogenetic classification the knowledge and consideration of the individual peculiarities is not sufficient, however important these peculiarities may be, or however early a period of development they may pertain to. The distinguished naturalist Fritz Müller, in his exceedingly valuable little work 'Für Darwin,' has given us a perfectly new systematic grouping of the Crustacea according to one of the earliest embryonal characters, namely the segmentation and the mode of curvature of the embryo within the egg (*Holoschista* and *Hemischista*, *Gasterotropa* and *Nototropa*); but he thereby furnished a proof that the groups proposed by him were any thing rather than natural groups ‡.

Among all properties of animals the biological conditions especially offer the least certainty in their classification, as even animals of admittedly different origin frequently live under exactly similar conditions, and in accordance with this not unfrequently also exhibit the same peculiarities. Thus, for example, the Cetacea and fishes live under exactly similar conditions, and therefore we find, in consequence of adaptation, not only the external form, but also the organs of motion, similarly formed, although, in fact, they are by no means nearly allied to one another. But even among the great marine Mammalia, according to recent investigations, the Sirenia prove to be essentially different from the true whales or Cetacea; and yet both forms of animals are externally so similar as to be confounded together, and they live under exactly the same conditions.

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* Forbes, 'Monograph of the British Naked-eyed Medusæ' (London, 1848).

† Eschscholtz, 'System der Acalephen' (Berlin, 1829).

‡ [Leipzig, 1864. English translation under the title of 'Facts and Arguments for Darwin' (London, 1869). The classification here cited is given by Fritz Müller ironically, to show to what results the application of certain authoritative dogmas would lead in the case of the Crustacea.—Transl.]

In order to avoid as far as possible these and similar errors all earnest and prominent systematists seek the true character of a group of animals (species, genus, family, &c.) not in its *individual* peculiarities, but in a certain *combination of all characteristic peculiarities*; that is to say, they found the character of the group upon a correctly combined summing-up of all its peculiarities, and, indeed, so that in each individual case the combined sum of the peculiarities always represents a definite animal-form, although the latter must not necessarily be assumed to be so unchangeable as was usual with the systematists of the old school.

Nowadays, therefore, it could not occur to any thorough naturalist or earnest systematist to classify any group of animals in accordance with any exclusively external or internal peculiarity observed either in an embryo, or in a larva, or in fully developed animals, with any one organic or biological condition.

If we now put the question, *how is a correct and really scientific classification of the animal kingdom to be created?* we may be permitted, in connexion with this, to assume as a principle that a classification which, being based upon morphological and embryological facts, also takes sufficiently into account the palæontological and biological data, and carefully follows these facts step by step, must in any case lead with most certainty to the final aim of science. This final aim is, however, nothing else than the knowledge of the law in accordance with which, by means of inheritance and adaptation, animals have originated from each other. If this be correct (as to which, in the light of Darwin's law of development, we cannot doubt for a moment), *then such a classification of the animal kingdom, such a system, can alone be accepted as perfectly natural, objective, and strictly scientific, which is capable of representing, in the form of a genealogical tree, the origin and gradual development of the world of animals.*

Another question is, *whether this ideal goal of our science will some day be really attainable, even after the labour of many generations.* Among the younger zoologists there may perhaps be some who esteem it possible to attain to such a goal; but if we seriously consider the many difficulties of this gigantic task and the insurmountable obstacles presented to it in certain directions, we must perhaps give up the hope that man, who in so many respects is able to govern nature, will really ever be in a position to construct a perfectly objective and truly phylogenetic system of nature. For the present, however, we may be content with the result if we succeed in approaching this final aim as nearly as possible, and in course of time at least in constructing such a system as will represent in part, although not perfectly, the true genealogical tree of the animal kingdom.

We will here at once look somewhat closely into those difficulties and obstacles which may not unfrequently confront the naturalist in his zealous endeavours to determine accurately the relationships of animals, and which readily give rise to errors.

1. Sometimes the difficulty may consist in this, that in the case of organisms with accordant structures one may not unfrequently be inclined to conclude, from the similarity of structure, that they are true blood relations, and further that this affinity must be closer the greater their similarity of structure is found to be. The cautious naturalist, however, will soon perceive that this principle, if very generally applied, easily leads to errors, for *in judging of a true blood-relationship that resemblance only can be of value which is produced originally by inheritance, but not that in which the agreement in structure has merely resulted from adaptation to similar vital conditions.*

The judgment of these circumstances may sometimes appear very difficult, in many cases even impossible. This, then, is a difficulty which may easily lead the zoologist astray by uniting in one and the same branch of the genealogical tree animals which are bound together by no close family tie, and this merely because they show an accordant structure, or because their larvæ or embryos prove to be more or less alike.

In phylogenetic classification therefore the zoologist must above all be able to distinguish well and accurately the homology originating by inheritance, or the so-called *homogeny*, from a similarity produced by adaptation or *homoplasy*[*].

Observation shows that by the action of similar conditions of life, and therefore merely by adaptation, similar and sometimes almost exactly identical organs may often be developed in animals which belong to perfectly distinct types or natural groups. As examples of this we may cite the chelæ occurring on the legs of crabs, and the palpi and chelicera of scorpions, as well as the pedicellariæ of the Echinodermata, all of which show a wonderful agreement both in structure and function, although no one would venture to assert that they have actually originated from each other by inheritance. In homo-

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[*] Ray Lankester, "On the use of the Term 'Homology,' in Modern Zoology," Ann. & Mag. Nat. Hist., 1870.

plasy or adaptive homology we also find the explanation of the formation of segments which occurs in many Platyelmintha, which therefore, as a simple phenomenon of adaptation, can by no means be equivalent to the metamere-formation of the Annelida. As a homoplasy of the same kind we also regard the resemblance between Rotatoria and Crustacea, which is erroneously interpreted by some authors, as well as that between the bills of birds and the maxillary horny sheaths of the Chelonia, and many others. Many erroneous views in this respect have already been refuted by more accurate investigations.

2. In consequence of Darwin's researches it is generally recognized as the *law of development* in the organic world, *that all organisms, animals as well as plants, are in a state of constant, although very slow, change and progressive development, so that, in general, the effort to attain greater perfection is predominant in the organic world.* From this constantly advancing progressive movement of phylogenesis many have erroneously concluded that all the simpler organisms living at the present day are only the representatives of similar animals which have continued in existence from an earlier period, and that consequently those natural groups to which they belong have never been at a higher stage of organization than that upon which they now stand.

In accordance with this principle many were at first of opinion that the whole animal kingdom, as well as its larger and smaller groups, might be quite simply embraced in several ascending series, just as these, in consequence of constant and unceasing advance towards perfection, had gradually become developed from the lowest to the highest stage of animal organization. It was soon found to be impossible, however, to establish the true genealogical tree of the animal kingdom upon this principle without falling into faults and errors. For Darwin's law of development, which in its final results is certainly *progressive, by no means excludes a retrograde movement or retrogression in certain stages of development,* as life presents not only progressive but also retrograde phenomena of movement, and absolute rest or unchangeability (*Stabilismus*) is an impossibility in Nature as in social life. In accordance with this law, by the action of unfavourable conditions of existence, and by means of natural selection, perfectly organized higher organisms may originate much simpler forms, which are, so to speak, degenerated by retrogression, although for this very reason better fitted for and corresponding to the new conditions of existence.

Of late the *parasitic animals* have been regarded as such animal forms, as well as those which live under ground, in mud, in dark caverns, and at great depths in the sea, or which, firmly adhering to other bodies, are incapable of any locomotion. We may refer here only to the Trematoda and Cestoda among the Platyelmintha, which evidently are nothing but the direct descendants of Turbellaria once leading a free existence, but gradually retrograded in consequence of a parasitic mode of life. The Cirripedia and Rhizocephala among Crustaceans, and the Linguatulidæ among the Arachnida, are nowadays justly regarded as such animal forms produced by retrograde metamorphosis, as also the Bryozoa, Brachiopoda, &c.

It may, however, not always be easy to recognize with certainty the cases of retrograde phylogenesis, or degeneration, and probably many forms which at present are ascribed to retrograde metamorphosis may in course of time prove to be progressive animal forms.

As in all other things, so also in science, man is inclined to overstep the bounds of sober reason, and to assume or assert *à priori* more than what facts directly prove. This applies so much to *the theory of retrogression or degeneration,* so widely diffused at the present day, that a natural philosopher has even ventured to set up the proposition that all animal forms are direct descendants of man, gradually degenerated by retrogressive metamorphosis!

Another view, which I believe to be erroneous, is also entertained by some *savants*, namely, *the opinion that the formation of body-segments (metameres), or the repetition of similar parts of the body, always leads towards the perfection of the organism.* In accordance with this assumption many naturalists are inclined to derive the unsegmented animal-forms, or those destitute of metameres, from supposititiously more perfect and allied animals, in which the body was once composed of numerous segments or metameres, and therefore originally segmented. Prof. Semper, of Würzburg, as is well known, has lately promulgated a similar opinion*, namely, that the Mollusca are to be regarded as the direct descendants of the Annelida, and consequently that the unsegmented Molluscan form has gradually been developed by retrograde metamorphosis from the Annelidan form. While it is possible, or even probable, that in many cases the formation of metameres, or the frequent repetition of equivalent parts, may lead towards perfection, observation often seems to prove the contrary. Thus, for example, among the Mollusca, we find generally in the Cephalopoda and Gasteropoda not the smallest trace of metamere formation (with the exception of the ex-

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* *Op. cit. suprà*, p. 315, note.

tremely anomalous form of the Placophora or Chitonacea, whose segmentation, moreover, is only external, imperfect, and apparent), and yet these stand upon an indubitably higher stage of organization than the Annelida composed of innumerable metameres. No one certainly will nowadays regard the Myriopoda as higher or more perfect animals than the Insecta or Arachnida, although in the latter it is the amalgamation of metameres that leads to greater concentration of the organization and individual perfection. The same is proved by the Vertebrata, the lower and less perfect forms of which are in general characterized by a greater number of metameres than the higher Vertebrata, the Amniota, which have been gradually developed from them by means of progressive phylogenesis.

In organic nature, as in human society, the law seems generally to prevail that, by the fusion of similarly constructed equivalent parts into larger complexes, an individually higher potentiality and perfection of the general organism always results. This is most strikingly shown to us in the formation of the head out of a certain number of metameres by the fusion of the anterior segments in the Arthropoda and Vertebrata; while, on the other hand, a frequent repetition of the more or less independent homologous parts or organs seems usually, in most organisms, to indicate an organic inferiority.

For these reasons many, especially among the American zoologists (A. Agassiz among others), justly regard the greater concentration of the organism, the so-called "*cephalization*," as the indication of a higher potentialization of the organization, a higher degree of perfection; and "*metamerization*," on the contrary, generally as the character of greater inferiority in the organism; so that the cephalized organisms, as it were, represent centralized states, and the metamerized mere federations.

All these considerations appear to be important and significant when we have to do with determining the natural position of an organism on the genealogical tree, and to state exactly to what branch or twig it belongs, in accordance with its affinities and derivations, and at which end (the upper or the lower) of the twig it is to be placed.

We see this best in the case of the Tunicata. The most esteemed and authoritative zoologists of the present day (Gegenbaur, Huxley, Ray Lankester, Giard, &c.) regard the near affinity of these animals with the lowest Vertebrata, especially with *Amphioxus*, as completely demonstrated, and this not alone because as regards their structure and development the above mentioned animals are surprisingly similar, and agree in most of their characters, but, above all, for the special and important reason that there seems to be evidence that the chorda which occurs in nearly all Ascidia in the larval period (with the sole exception of the Molgulidæ) can by no means be regarded as an organ acquired by adaptation during the larval period, but as one which they have obtained originally by inheritance from their formerly more perfectly organized ancestors. We may therefore, from the transitory presence of the chorda, and its, in most cases, complete retrogression at a later period, draw the correct conclusion that the Tunicata were not produced by progressive phylogenesis, but that they must have originated by retrogression or degeneration from other more highly organized ancestors, similar, but provided with a fully developed chorda.

If we now suppose the case that of the known Tunicata the *Appendiculariæ* and all those numerous Ascidia which possess a chorda in the larval period had by chance disappeared without leaving any traces, we may ask, what proof should we then have of the retrograde metamorphosis of the Tunicata? It might then easily happen that we should place them at the topmost stage of some lower but progressive series of animals, and therefore classify them incorrectly in the system.

It will be seen from this that for correct classification caution and sober reason are above all necessary, especially in those cases where we have to do with the accurate determination of the relationships of an isolated group, with the development and other essential peculiarities of which we are only imperfectly acquainted.

When we take all this into consideration it appears clearly that *side by side with progressive phylogenetic series there are also retrogressive series and groups, which, in spite of frequently very divergent structure, may nevertheless not unfrequently be very nearly allied.*

Darwin's law of development justifies the assumption that among the many partly progressive, partly retrogressive series there must certainly exist one progressive developmental series, which commences below with a perfectly simple plastid and terminates above in man; but to decide which of the numerous branches and twigs of the genealogical tree of animals are truly progressive, or which of them owe their existence to a retrogressive phylogenesis, can only become possible in course of time, and then with any certainty, or at any rate with probability, only upon the foundation of embryological and morphological investigations. So long, however, as we have no indubitable grounds or facts which directly indicate the retrogression or degeneration of a given animal-form or group, we shall proceed most securely in judging of its derivation if we for the time assume it to have been progressive.

Nevertheless there are animals with regard to which we may assume, if not with certainty at least with much probability, that they have originated by retrograde development from other more perfect animals. Thus, among others, it seems very probable that the Dicyemidæ, which E. van Beneden regards as an independent progressive animal-form standing between Protozoa and Metazoa, and refers to the group Mesozoa, which he has established, are really only forms of some Platyelminth, degenerate in consequence of a parasitic mode of life; just as the Myzostoma are Chætopod worms degenerated by retrograde metamorphosis. It is, moreover, probable, although not certain, that among the Protozoa forms occur which possibly owe their existence to a retrograde metamorphosis and have originated from Metazoa. Nay, the possibility does not seem to be excluded that even the Polyps and Corals belong to the retrogressive animal-forms, and perhaps are nothing else than the peculiarly modified and degenerated descendants of some originally free-swimming bilateral form of worm. Even in the great group of the Vertebrata it is a highly interesting question *whether* Amphioxus *and the Cyclostomi are not the descendants of some more highly organized craniate Protovertebrate, constructed after the type of the Monorhina, which has become in course of time entirely extinct*, and in which both the jaws and the paired limbs were still wanting.

3. Besides the difficulties here mentioned which come in our way in the classification of the animal kingdon, but which seem to be superable sooner or later by further investigation and unwearied labour, we must consider one obstacle, the power of which the human mind will never be able completely to overcome.

Thus, for a truly genealogical and phylogenetic classification of the animal kingdom we need not only an accurate knowledge of the existing forms, but also of those which have long since been extinct, and, further, a comparison of these forms with each other, for palæontological facts, as is well known, are of no less value than the knowledge of the embryological and morphological characters of living animals.

According to Darwin's developmental law, we may conclude that very numerous *transitional forms* between the different groups of animals must formerly have existed; this is the necessary condition, the natural result of the theory of evolution. Matters are quite different, however, when we consider existing nature. We see that existing animals are all separated into larger or smaller groups, more or less removed from each other. The individual members of these groups frequently stand in very close relationship to one another, but the groups themselves are generally separated by smaller or larger intervals or gaps, and these gaps are now usually not occupied by intermediate forms. Every isolated group in the system, many families, orders, and classes furnish plenty of examples of what has just been said.

It would be a great mistake if any one were to conclude at once, from the total absence of intermediate forms, that such had never existed in nature. As experience shows, it is only in very rare cases and under favourable conditions that the fossil forms remain quite unaltered, leaving out of consideration the fact that a great number of them, such as the Cœlenterata, Tunicata, and Protovertebrata, as well as the greater part of the Vermes, owing to their softer texture, could not, even under the most favourable circumstances, leave any trace behind them.

What great value attaches to the knowledge of palæontological facts, and how important it is for the determination of the phylogenetic relationships between the different groups, as well as for a correct classification, is best proved by the most recent position of our system. Thus the character or definition of the class of Birds appears something quite different, if we take into consideration exclusively the existing forms, or if we include the extinct *Archæopteryx* and the fossil *Odontornithes* (toothed birds), lately discovered by Prof. Marsh in North America, such as *Hesperornis regalis* and *Ichthyornis dispar*. Not only in this class, however, but in nearly every more or less isolated group, forms occur, the natural position of which in the system can only be correctly determined by comparison with the known palæontological types. If we consider thegreat number of extinct forms the traces of which are still unknown to us, we must regard the establishment of a complete genealogical and phylogenetic system as still impossible, considering the imperfection of our present palæontological knowledge. Finally, if we think of those delicate and soft animal forms whose traces are entirely lost, and which therefore will for ever remain unknown to the naturalist, it becomes more than probable *that we shall really never be in a position to establish and completely construct an absolutely perfect genealogical tree of the whole animal kingdom.*

For the present, however, we must content ourselves with the best attainable, and we may be satisfied with the result of our labour if, supported on the morphological and embryological facts already collected and ascertained, and considering the known palæontological forms, we endeavour with our full knowledge and conscientiously, by a systematic grouping of the animal kingdom, to express, to the best of our power, the relations existing between the different animals, as well as the natural position of the groups and their individual members.

Now that we have discussed in detail the general principles of classification, as well as the precautions necessary for a natural grouping of animals, I may be permitted, as a small contribution towards the construction of a phylogenetic system, to expound my views as to the relationships of the different groups, although only tentatively, in the form of a genealogical tree (see p. 334). In the grouping of the different stems, as well as in their relations to one another, this agrees in many respects with others, but nevertheless, as regards certain ramifications and groups of the genealogical tree, it differs, not unessentially, from other similar attempts. The following remarks may serve to explain and elucidate our subject.

First of all I must notice particularly that, although the denominations " Protozoa " and " Metazoa " are almost universally employed in modern zoology for the two principal groups of the animal kingdom, I think it would be better to call the former " Protoplastica," as a word which expresses more accurately and better the nature of these lowest animals; and the latter " Blastodermica." In these latter the body never consists of one or more homogeneous protoplasmic cells, but is always composed of heterogeneous cells and tissues, which tissues are originally produced from two different blastodermic cell- or germ-layers, namely, from the primitive *ectoderm* and *entoderm*.

The animals which are developed with such a blastoderm (Blastodermica) divide, from a phylogenetic point of view, into two main branches.

The smaller main branch is represented by those blastodermic animals which, remaining at a low stage of development, possess only a simple primitive nutritive cavity, formed by the ectoderm alone, without any trace of a cœloma. These lower Metazoa (Blastodermica), which are nourished by a primitive nutritive cavity (*archenteron*), we therefore name " Archentera."

To the Archentera there belong, according to our views, as separate ramifications or phyla, the *Porifera* (Sponges) and the *Cœlenterata.*

With regard to the Porifera or Sponges, I by no means share in the opinion of those naturalists who regard these animals somewhat as aborted or degenerated Anthozoa, and who, partly for this reason and partly on account of the similarity in structure and development, refer them to the stem of the Cœlenterata. It is possible that they only form a transition between the Protozoa and Metazoa, and perhaps are nothing else than colonies or cell-stocks composed of different kinds of cell-individuals, so that a part of the cells have the duty of alimentation and reproduction, while the other cells perform the functions of respiration and movement. It is well known that Clark, referring to the presence of the peculiar collared cells or flagellate cells which have hitherto been found in no other blastodermic animals, has brought the Sponges into direct connexion with the Flagellata, described by him under the names of *Salpingœca* and *Codosiga* (= *Cylicomastiges,* Bütschli), and explained them as resembling the colonies composed of Flagellata. This view may certainly be very well brought into agreement with the still free-swimming larvæ of the Sponges, but it most decidedly contradicts the further developmental characters of the Sponges, especially taking into consideration the recently acquired embryological facts, according to which the Porifera differ in no small degree from the other Metazoa both in the formation and in the function of the germ-lamellæ. If this be really the case, we must regard them logically as a group of animals equivalent to the Metazoa, but differing from them.

So long, however, as the developmental history of these animals is not accurately and thoroughly known, I regard it as more logical to refer them for the present to the Metazoa, and to regard them as a special type or ramification of the Archenterate main-branch, diverging from the Cœlenterata.

Another, far stronger, main branch of the blastodermic animals combines all those animal-stems which, with the exception of some Platyelmintha (Turbellaria, Trematoda, and Cestoda), are all provided with a secondary alimentary canal (*metenteron*), composed of two layers, namely, the entodermal layer and the inner mesodermal lamina (*splanchnopleura*), and enclosed by a cœloma. As the cœloma generally, as is well known, originates by constriction from the archenteron, and indeed from the parenteric processes or diverticula of the latter, we characterize all those blastodermic animals or Metazoa which possess a perfect secondary alimentary canal, modified in the way just mentioned, with the name of *Metentera*.

To the great main-branch of the Metentera belong, above all, in our opinion, the vermiform animals or Helminthozoa. According to all extant investigations, these animals form one of the oldest of the great stems or phyla of the whole genealogical tree, most important from a phylogenetic point of view, and most interesting anatomically and embryologically. The group Helminthozoa embraces very many different forms, which, as regards both their structure and their mode of development, differ so much from each other that it can hardly be regarded as too bold an assertion to say that, in the whole animal kingdom, there is hardly another stem that would embrace such different and sometimes widely divergent modifications or classes. For this reason, also, it seems scarcely permissible to regard the Vermes as forming an equally unitary animal-type, as, for example, the Arthropoda, Echinodermata, Cœlenterata, and other great groups. Thus, among other things, the Platyelmintha (with the sole exception of the Nemertina) are distinguished not only by greater simplicity of organization, but also essentially by the absence of a true cœloma, from all other Vermes, and even from all Metentera. Nay, from this last-mentioned negative character (the absence of a cœloma) they might quite logically be regarded as a special group of the Archentera. We must not forget, however, that the Platyelmintha which are destitute of a cœloma (Turbellaria, Trematoda, and Cestoda) are, on the other hand, nearly related to the Nemertina, and through these to the other groups of the same stem, all of which are furnished with a cœloma; also that the other groups of the Vermes deviate from one another in many respects, and sometimes considerably, especially when we take into account the segmentation of the ovum and the mode of formation of the cœloma. Chiefly for this reason we hold it necessary for the present still to regard the Platyelmintha as united with the other groups of Vermes in the common stem of the Helminthozoa, although, by many naturalists, attempts have already been made to divide this stem into several subordinate stems or subphyla. But if we consider how imperfect the knowledge still is that we possess as to the structure and development of the Vermes, we must regard all such attempts at the present day as premature.

The results of the numerous investigations hitherto made seem only to prove one thing, namely, that the stem Vermes is perhaps very well divisible into two or several divergent branches—the group of the *Scolecida* (Platyelmintha with the exception of the Nemertina) and the group of the *Annelida*. Of these latter, however, the *Polychæta* differ essentially in their mode of development from the *Oligochæta*, and, moreover, as is well known, there are many other forms, such as the *Nematoda*, *Acanthocephala*, *Gephyrea*, *Chætopoda*, *Enteropneusta*, and *Rotatoria*, which differ not inconsiderably, in many respects, not only from the above-mentioned Annelida and Scolecida, but also from one another.

From the consideration of all these facts, from the standpoint of phylogenesis, in accordance with the present state of science, only one thing can be accepted as established, namely, *that the Helminthozoa form on the genealogical tree of the animal kingdom, a knot, which is at present not quite untiable, from which probably all the other higher stems have branched off* (see the Table, p. 334); and, consequently, there is no doubt that the main stem of the Helminthozoa was of the greatest importance in the origin and descendence of the higher types.

From the results of recent embryological investigations it is sufficiently clear that the embryos, as well as the free-swimming ciliated larvæ, of different Vermes more or less resemble the larvæ of the Echinodermata, Bryozoa, Brachiopoda, many Mollusca, and the Provertebrata (Tunicata and Leptocardii). From the remarkable similarity of the conditions of development of these animals it is further to be assumed that these might all have originated by the process of natural selection from one or more simple, vermiform, primitive forms. Nevertheless we must freely admit that the known facts of embryology, as well as all the hypotheses built upon these facts, by no means suffice for the final decision of the question, From what special primitive form have the Mollusca, Bryozoa, and Brachiopoda, the Arthropoda and the Provertebrata been phylogenetically developed? Both in amount and in importance the facts at present known are only capable of proving this much: that the great stem of the Helminthozoa very probably forms the starting-point for the higher animal-stems of the Echinodermata, Arthropoda, Malacozoa, and Chordovertebrata.

Further, as regards the opinion of Prof. Semper and other zoologists, according to which the Annelida are specially adopted as the ancestors of the Vertebrata, I may here be permitted only to remark that the facts cited for the establishment of this opinion (the segmental organs or primitive kidneys) do not, in my estimation, suffice to demonstrate indubitably that the Annelida are in reality more nearly allied to the Vertebrata than these latter to *Amphioxus* and the Tunicata. Nay, it even seems very probable that the resemblance founded upon the segmental organs *does not owe its existence originally to heredity*, but that it has originated only in consequence of adaptation to similar conditions of existence, and consequently is to be referred to a so-called *homoplasy*, which, as has already been explained in detail, is not sufficient for the demonstration of a true blood-relationship. In my opinion, that other hypothesis is much more acceptable, according to which both the Annelida and the Provertebrata have originally been produced from worms whose body as yet exhibited no segmentation at all, such as we may still see among the Turbellaria, Nemertina, Chætognatha, Enteropneusta, and Nematoda.

With regard to the Bryozoa and Brachiopoda, my tendency is towards the opinion *that these animals belong to the great stem of the Malacozoa.* It appears exceedingly probable that they branched off very early from the true Mollusca, as is sufficiently proved by a careful comparison of their structure and conditions of development, and especially the similarity of their larvæ (modified trochospheres). This view finds further support in the interesting form *Rhabdopleura*, (a divergent form of the Phylactolæmata), which becomes of the more importance because, in its external form and internal structure, it is very similar not only to the Brachiopoda, but also (according to Ray Lankester's investigations) to the embryos of a Lamellibranchiate, namely *Pisidium.* All this may serve as evidence that the Bryozoa, as also the Brachiopoda, have originated with the true Mollusca from one and the same main stem, and, indeed, very probably by their having, at a very early geological period, gradually adapted themselves to a sedentary mode of life, differing from that of the remaining progressive Malacozoa.

Upon these facts and considerations we have thought that we could best represent the true relationships of the Bryozoa and Brachiopoda to each other and to the true Mollusca by dividing the main stem of the Malacozoa into two branches or subphyla, of which the larger branch embraces the so-called Mollusca, *i. e.* all the more or less *progressive* forms of this stem (Lamellibranchiata, Scaphopoda, Placophora, Gastropoda, Pteropoda, and Cephalopoda, as distinct classes), while the other branch, namely the subphylum of the Molluscoidea, includes the Brachiopoda and Bryozoa, originating by means of retrogressive phylogenesis.

With regard to the groups belonging to the stem of the Arthropoda, we must remark that, as is well known, the number of Arthropoda breathing by tracheæ has lately, since the structure and development of *Peripatus* have been more accurately known, been increased by a new class, namely that of the Protracheata (of Balfour and others). Since Moseley succeeded in proving that these animals, which for a long time were referred to the Vermes under the name of *Onychophora*, really respire by tracheæ, and were also distinguished from the other Arthropoda by the possession of quite divergent, primitively constructed, and foot-like buccal organs *, I regard it as perfectly right to unite this small but interesting group, after the example of recent naturalists, with the stem of the Arthropoda as a separate branch of the Tracheata.

In like manner I have regarded it as more judicious and more in accordance with nature to establish in the class Crustacea, besides the chief groups hitherto adopted (Thoracostraca, Arthrostraca, and Entomostraca), a fourth group, namely that of the Palæostraca. This section of the Crustacea, which includes the Trilobita and the Xiphosura, as well as the fossil Merostomata first described by H. Woodward, is distinguished from all others by the fact that the mouth-organs of the forms belonging to it are very different from those of the other Crustacea, and either foot-like or rudimentary, or sometimes even entirely wanting (Trilobita).

Finally, as regards the *Chordo-Vertebrata*, I find myself led in some points to adopt views somewhat diverging from those of other naturalists. Thus I agree perfectly with Balfour, Ray Lankester, &c., that we must unite the Urochorda (Tunicata) as well as the Cephalochorda (Leptocardii) with the stem of the Vertebrata; but with respect to the Cyclostomi or Monorhina I by no means share the opinion of those *savants*. The Cyclostomi are in fact distinguished by a great number of partly positive, partly negative, characters of importance, which never occur elsewhere in other fishes (Selachii, Ganoidei, Dipnoi, and Teleostei), or, indeed, in any true Vertebrata even during the embryonal period; and by these peculiarities they evidently, on the other hand, nearly approach the Leptocardii and Tunicata. These characters are:—

a. The absence of the mandible.
b. The absence of paired extremities.
c. The absence of the *nervus sympathicus*.
d. The originally simple and unpaired nasal cavity (olfactory cavity) with a simple external dorsal olfactory aperture.

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* Phil. Trans. vol. clxiv. (1874).

e. The composition of all the nerves of exclusively white elements.

f. The direct course of the *nervi optici* to the two eyes without any crossing.

g. A remarkably large and wide stomadæum, or the remarkable size of the anterior portion of the alimentary canal representing the stomadæum.

h. The occurrence of a hypopharyngeal groove, always developed at least during the larval period.

i. The smoothness and softness of the integuments, as well as the absence of any formation of scales.

k. Absence of the lateral organs which are developed elsewhere in all fishes and Amphibia (in the latter in the larval period).

If the Cyclostomi be compared with *Amphioxus* and the Tunicata, we find, further, that of all these the Cyclostomi alone are possessed of a primitive cartilaginous skull, in which a præchordal part is already developed. If, however, we examine this Cyclostome skull more closely, we arrive at once at the conviction that, as regards its external form and internal structure, it presents essential differences from the cartilaginous skull of fishes (Selachii, Dipnoi, Ganoidei).

The blood is red, like that of other fishes, but the blood-corpuscles are of a circular and not of an elliptical form.

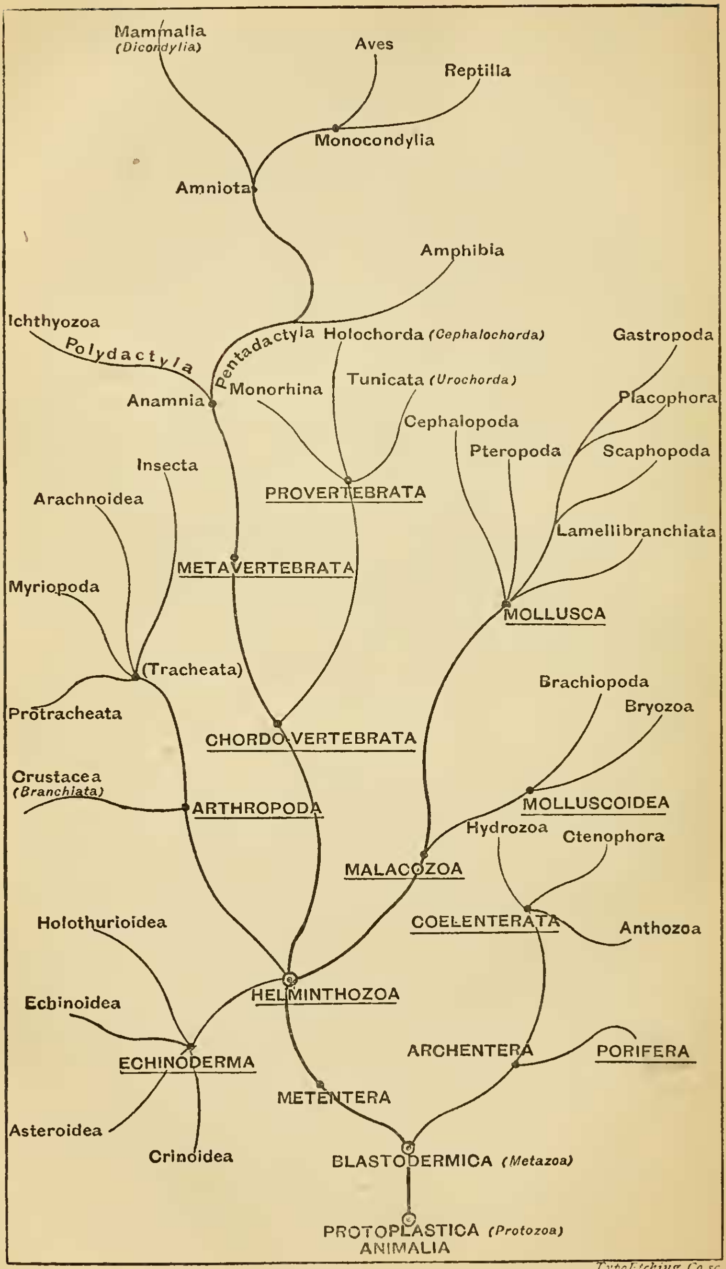
The segmentation of the ovum, as shown by recent investigations, is not regular, as in *Amphioxus* and the Tunicata, but irregular and amphiblastic (as in *Acipenser* and the Batrachia). But if we consider that the mode of segmentation may sometimes be quite different even in nearly allied animals, and that, moreover, the conditions of existence of the animal may exert a great influence, if not directly, yet indirectly, upon the process of segmentation, we must regard the different mode of segmentation as by no means a safe criterion in judging of the relationships of the Cyclostomi. On the other hand, it seems to us to be of much greater importance that the earliest larval form of *Petromyzon* is very like *Amphioxus,* and then subsequently becomes transformed first into the *Ammocœtes*-form, and finally into the definitive form.

If, then, we take all these peculiarities into consideration, and weigh them all carefully, it appears clearly that the number of bonds which unite the Cyclostomi with *Amphioxus* and the Tunicata is greater than the number of characters which those animals have in common with the Selachii and the other fishes.

I think, therefore, that the relationships between the different classes of the Chordo-Vertebrata may be expressed by a more natural grouping, if I divide their main stem into two divergent branches or subphyla, one of which, *the subphylum of the Provertebrata*, or *Primitive Vertebrata*, includes the more or less reduced or retrogressive forms of simpler structure, furnished with a wide stomadæum, a hypopharyngeal groove, and an unpaired median olfactory organ, but destitute of a mandible and of paired limbs, as well as of a *nervus sympathicus* and of true lateral organs, to which belong, as distinct classes, the Tunicata, Leptocardii, and Monorhina. The other, larger branch, *the subphylum of the Metavertebrata*, or true Vertebrates, would then embrace the true fishes or Ichthyozoa (Selachii, Ganoidei, Dipnoi, and Teleostei), originating by progressive phylogenesis the Amphibia, Reptilia, Birds, and Mammalia, all of which are furnished with mandibles, paired extremities, paired nasal cavities, and a *nervus sympathicus* (see Table, p. 334).

As regards the forms of the *Provertebrata* living in the present geological period, *it appears very probable that they are the descendants of the more perfect free primitive Vertebrates which existed in Palæozoic times, even before the first appearance of the Selachii, of which, however, a great part has gradually died out and disappeared entirely in consequence of the occurrence of unfavourable conditions of existence in course of time.*

And if we consider, in conclusion, that the still existing forms of the *Provertebrata* are for the most part characterized by a semi-parasitic or sedentary mode of life, it may be assumed with some probability that they are indebted for their preservation to this their peculiar mode of life. Thus, while some of their formerly free-living ancestors had the good fortune to become transformed by natural selection in the way of progressive phylogenesis into *Metavertebrata*, or true Vertebrates, and others, on the contrary, in course of time have gradually died out, the rest were able, in consequence of retrogressive metamorphosis, to maintain their existence, although with a reduced structure of body, under the allotted conditions of existence, uninjured to the present day, in the form of Tunicata, Leptocardii, or Monorhina.



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